PRESENTATION
61-25

Modeling the bedrock surface in Indiana with contouring software

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ABSTRACT

Most contouring algorithms can quickly generate numerous surfaces that honor bedrock surface (BRS) data, but automated BRS models are often poor geologic interpretations because a single combination of contouring algorithm and gridding parameters may not work best throughout a map area. Modeling that works well where deeply incised paleovalleys are present beneath thick glacial cover break down where thin sheets of unconsolidated sediment are draped over the BRS, and vice versa. One way to overcome this problem is to subdivide a map area and apply different BRS modeling techniques (independent, dependent, or coincident) based on inferred relationships between the BRS and a digital elevation model (DEM) of the topographic surface.

Independent BRS models are based on the assumption that the BRS and DEM are unrelated. These models focus on buried BRS features such as paleovalleys. Independent BRS models are made by first developing a computer-generated BRS model that honors the data and roughly outlines BRS features. Breaklines and phantom data points are added to mold the computer-generated surface into a geologic interpretation that fits the data and shows an interpretation of the shape, continuity, and connectivity of buried paleovalleys.

Dependent BRS models are based on the assumption that the BRS is sub-parallel to the topographic surface. These models focus on the thickness of unconsolidated deposits that is draped over the BRS. Dependent BRS models are generated by subtracting a model of unconsolidated deposit thickness from a DEM trend surface that filters out minor DEM relief not related to the shape of the BRS. These models work best where changes in the thickness of unconsolidated deposits are gradual.

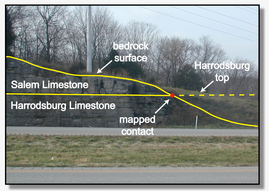
The coincident BRS model is based on the assumption that the BRS and DEM are essentially equivalent. These models use DEM data as the BRS model and are employed where bedrock outcrops or where soil maps show thin soils derived from underlying bedrock.

Combining areas where these models are applied yields a digital BRS that fits the data and blends BRS interpretations appropriate for various Quaternary terrains. The digital BRS is used to automate the computation of unconsolidated deposit thickness and to compute the distribution of bedrock units on a geologic map.

GEOLOGIC MAPPING TECHNIQUE

A variety of software products is available to automate many of the tedious tasks associated with geologic mapping. Contouring software is an especially useful tool because it can be used to create 3-D models of the surfaces that bound rock units and then generate a geologic map by computing appropriate intersections between these surfaces. The index map to the right shows the location of Indiana Geological Survey (IGS) STATEMAP projects where contouring software has been and is being used to make geologic maps.

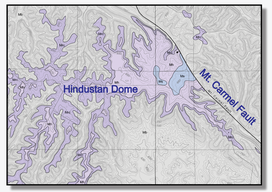
STATEMAP
Bedrock Mapping Projects



The photograph to the left uses a road cut to illustrate how a rock-unit contact is computed with contouring software. The computed Salem/Harrodsburg contact is the polyline that satisfies the grid math equation:

bedrock surface - Harrodsburg top = 0

The figure to the right shows a portion of a recently completed geologic map that illustrates the detail that can be achieved using this mapping technique (scale: 1:24,000).



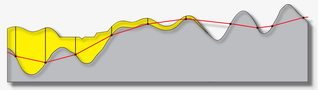
PROBLEM

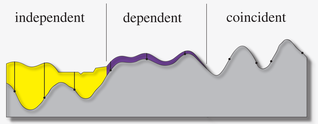
Constructing an accurate 3-D bedrock surface (BRS) model is an essential component of making geologic maps using contouring software. In Indiana, the BRS is a complex surface representing the accumulated effects of numerous erosional events. Petroleum wells, water wells, natural exposures, excavations, seismic refraction, soil maps, and the geologic literature provide thousands of data points that document the BRS. Most contouring algorithms can quickly generate smooth surfaces that fit these data. But computer-generated BRS models that simply connect the available data points are generally poor geologic interpretations because:

1) contouring that works well in one geologic setting may produce poor results in another setting;

2) contouring algorithms produce smooth surfaces that fit the data but do not recognize complex geologic features such as paleovalley systems.

The idealized cross section to the right shows typical features of a BRS documented by a limited number of data points (black dots). The red line illustrates how a contouring algorithm might connect the data points but fail to reveal BRS features and, worse yet, result in a BRS model that crosses the topographic surface.





One way to overcome this problem is to subdivide a map area, as shown in the idealized cross section to the left, and apply different BRS modeling techniques (**independent**, **dependent**, or **coincident**) based on inferred relationships between the BRS and a digital elevation model (DEM) of the topographic surface.

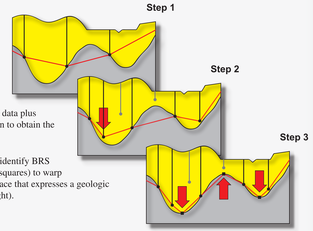
INDEPENDENT BEDROCK SURFACE MODELS

Independent BRS models are based on the assumption that the BRS and DEM are unrelated. These models focus on buried BRS features such as paleovalleys. Independent BRS models are made by first developing a best-fit computer-generated BRS that roughly outlines BRS features and then modifying that surface to make it into a geological interpretation that shows the shape, continuity, and connectivity of buried paleovalleys. Typical modeling steps are outlined and illustrated below.

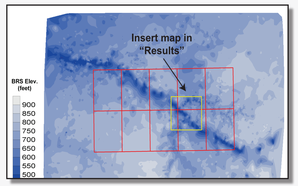
Step 1 (first approximation): Use an exact gridding algorithm to construct a surface that connects data documenting the exact position of the BRS (red line in figure to the right).

Step 2 (second approximation): Compare data that document a minimum depth to the BRS to the first approximation. Discard minimum-depth data that lies above the first approximation surface and grid exact BRS data plus minimum-depth data that lie below the first approximation to obtain the best computer fit (red line in figure to the right).

Step 3 (interpretation): Use the second approximation to identify BRS features. Add breaklines and phantom data points (black squares) to warp the second approximation into a computer-generated surface that expresses a geologic interpretation and fits the data (red line in figure to the right).



Southwest Wabash Quadrangle Map Area



The map to the left is a second approximation BRS for ten 7.5-minute quadrangles (outlined in red) in the southwestern portion of the Wabash 60 x 30 minute quadrangle. The surface is based on 26,432 exact and 7,508 minimum-depth BRS data points. The Teays Paleovalley is easily recognized as the northwest-southeast trend of deep depressions, but the paleovalley's shape is obviously wrong. Breaklines and phantom data points were used to warp this surface into an interpretation of paleovalley shape and connectivity. The final BRS map is shown in the "Results" panel.

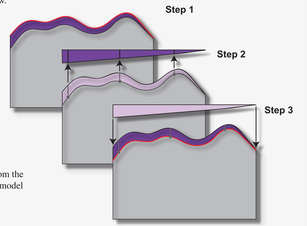
DEPENDENT BEDROCK SURFACE MODELS

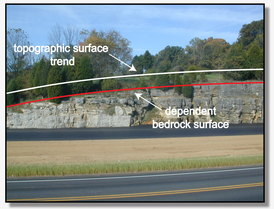
Dependent BRS models are based on the assumption that the BRS is sub-parallel to the topographic surface. These models focus on modeling the thickness of unconsolidated deposits and work best where changes in the thickness of unconsolidated deposits are gradual. Typical modeling steps are outlined and illustrated below.

Step 1: Construct a trend surface that filters out minor relief on the topographic surface (red line in figure to the right).

Step 2: Compute the thickness of unconsolidated deposits using unconsolidated thickness relative to the trend of the topographic surface (purple wedge in figure to the right).

Step 3: Subtract the thickness of unconsolidated deposits from the trend of the topographic surface to obtain a dependent BRS model (red line in figure to the right).



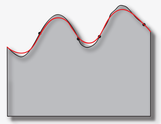


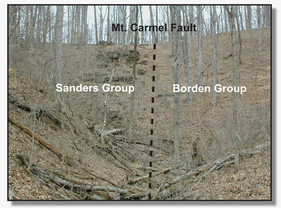
The photograph to the left shows part of a road cut sliced through a hill in southern Monroe County, Indiana where a thin blanket of unconsolidated deposits is draped over the bedrock surface. The white line is a trend of the topographic surface that ignores minor topographic features. The red line illustrates how a dependent BRS model parallels the trend of the topographic surface to achieve a BRS approximation.

COINCIDENT BEDROCK SURFACE MODELS

Coincident BRS models are based on the assumption that the BRS and topographic surface are essentially equivalent. These models are employed where bedrock outcrops or where soil maps show thin soils derived from underlying bedrock. Coincident BRS models are generated by substituting DEM data into the BRS model.

The figure to the right illustrates minor distortions that occur when a low-pass filter is used to remove DEM artifacts (red line in figure to the right). Filtering lowers narrow ridges and raises narrow valley bottoms. Coincident BRS models based on filtered DEM data include these distortions but generate smooth computed crop lines.



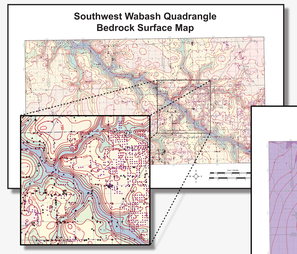


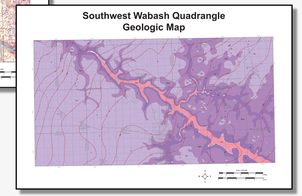
The photograph of the Mt. Carmel Fault to the left illustrates two kinds of coincident BRS terrains found in Monroe County, Indiana. Carbonate rocks are exposed to the left of the fault (downthrown side) and clastic rocks to the right of the fault (upthrown side) are covered with thin soils.

RESULTS

The map below is a computer-generated BRS map of the southwestern portion of the Wabash 60 x 30 minute quadrangle constructed by combining independent and coincident BRS models. The map shows a section of the deeply incised Teays Paleovalley and its tributaries. The geologic map to the right of the BRS map is a computer-generated geologic map produced by intersecting surfaces representing the tops of Silurian and Ordovician rock units with this BRS model.

Southwest Wabash Quadrangle Map Area





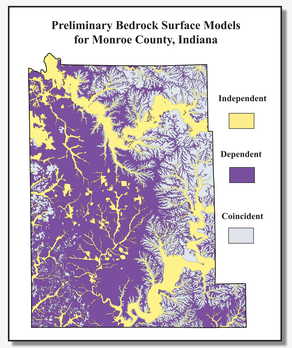
The computer-generated BRS map illustrated above is shown at a scale of 1:250,000. The insert shows a portion of the map at its publication scale, which is 1:100,000.

The computer-generated geologic map illustrated above is shown at a scale of 1:250,000. The scale of the published map is 1:100,000.

CURRENT WORK

A current IGS STATEMAP project focuses on mapping bedrock geology in Monroe County, Indiana at a scale of 1:24,000. The unconsolidated sediments that overlie the BRS in Monroe County range from paleovalley fills that exceed 100 feet, to thin blankets of loess and terra rossa on upland surfaces, to broad areas of thin soil and exposed bedrock. The map below shows a preliminary partitioning of Monroe County into areas where independent, dependent, and coincident BRS modeling will be applied. The boundaries of the models will shift as Quaternary mapping advances but this status map is sufficiently complete to shown regional patterns and the intimate intertwining of BRS models that is necessary to make large-scale, computer-generated geologic maps.

Monroe County Map Area



CONCLUSIONS

The techniques described here make it possible to accurately communicate how a geologic map is constructed. Combining the areas of independent, dependent, and coincident BRS modeling yields a digital BRS that fits the data and blends BRS interpretations appropriate for various Quaternary terrains. The resulting digital BRS can be used to:

1) compute the distribution of bedrock units;

2) automate the computation of unconsolidated deposit thickness.